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THE MODELED CURVES (MODCURVES) PROGRAM

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REVIEW AND APPROVAL STATEMENT

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PREFACE

The MODCURVES (Modeled Curves) program was developed by the United States Air Force Environmental Technical Applications Center's Environmental Simulation Branch (USAFETAC/DNY), now part of the Simulation and Technology Branch (USAFETAC/SYT). The program tasking originated at the Air Weather Service Centralized Support Division (AWS/DOOX) after 7th Weather Wing (since disestablished) led an AWS-wide effort to solicit operational requirements for climatological databases on microcomputers. This program, along with other microcomputer-based programs such as MODCV (Modeled Ceiling and Visibility), is for use by base weather station forecasters as well as by those deployed in the field.

The purpose of this tech note is to tell AWS STAFFMETs, analysts, and forecasters how the MODCURVES program works. It also describes the statistical techniques and algorithms used that generate conditional and unconditional diurnal and annual curves of meteorological variables that tend to exhibit cyclic behavior.

The MODCURVES algorithms, based on commonly known and proven statistical techniques, were developed by Capt James T. Kroll, USAFETAC/DNY, in 1989.

For more information, call USAFETAC/SYT at DSN 576-5412 or Commercial 618-256-5412.

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Chapter 1

INTRODUCTION

1.1 Description. MODCURVES (Modeled Curves) uses Fourier coefficients to reproduce diurnal and annual curves of temperature, dew point, relative humidity, altimeter setting, and pressure altitude. Fourier coefficients are calculated for several sets of time series data. Currently, coefficients for the 5th, 50th, and 95th percentile values of the five meteorological variables are used as input to the MODCURVES program, which produces unconditional climatologies for all three percentiles as well as conditional climatologies based on combinations of wind direction and sky cover categories. The user also has the option to input initial weather conditions; the program incorporates these initial values and adjusts the diurnal curve.

1.2 Requirement. With the acquisition of microcomputers by base weather stations in the mid 1980s, 7th Weather Wing led an AWS-wide effort to determine and establish operational requirements for climatological databases accessible by microcomputer. Since consideration was also given to meteorological analysis/forecast program requirements, Air Weather Service (AWS) field units suggested microcomputer access to diurnal and annual curves. These suggestions were narrowed to include temperature, dew-point temperature, relative humidity, altimeter setting, and pressure altitude. In June 1989, Capt James T. Kroll, USAFETAC/DNY, developed a model that would take time-series data for the percentile values of given meteorological variables to produce diurnal and annual curves for that variable. The results are described in the following chapters.

Chapter 2

MODCURVES METHODOLOGY

2.1 Fourier Series. A Fourier series is generally used to model a time series of meteorological data. This technique, which allows us to reconstruct a large time series using only a few coefficients, is the data compression method used by MODCURVES.

MODCURVES performs statistical analysis of times series data. A "time series" is a collection of numerical observations arranged in chronological order; Figure 2-1 is an example.

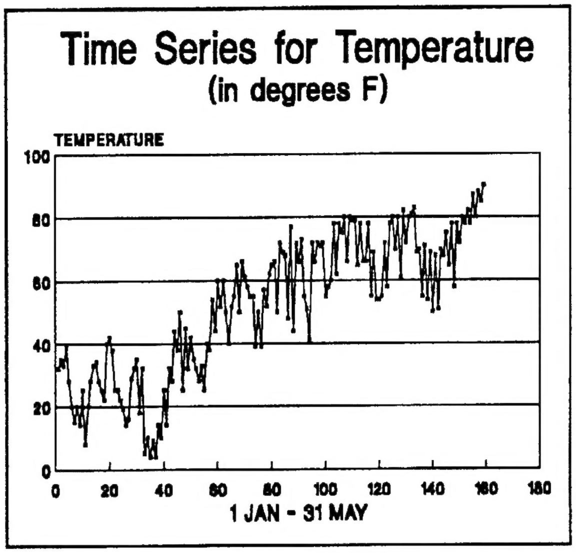

Figure 2-1. Time series for temperature.

We generally assume the intervals of time between observations to be equally spaced (Bloomfield, 1976). The purpose of statistical analysis of a time series is to understand the characteristics of its periodic and irregular oscillations. In meteorology, statistical analysis is used to predict the future behavior of the time series.

A time series analysis begins by recognizing that the total variation of a meteorological variable can be represented as the sum of several oscillations (e.g., annual and diurnal cycles). The most commonly used time-series analysis in meteorology is *spectral* or Fourier analysis. Its use increases the understanding of the physical behavior of regular oscillations.

Although there are mathematical requirements for determining the types of functions that can be modeled with a Fourier series, suffice it to say that *any* function that represents the time behavior of a real physical variable meets these requirements.

The following discussion of the Fourier series is based on Panofsky and Brier (1958). We will use the notation $F(t)$ to represent the time series of meteorological data (*e.g.*, the mean temperature at each hour for a given month). The series $F(t)$ can be obtained at any given point t using:

$$F(t) = \bar{F} + \sum_{m=1}^{N}\left[A_m \sin\left(\frac{2\pi}{P}mt\right) + B_m \cos\left(\frac{2\pi}{P}mt\right)\right] \quad (1)$$

where F is the mean, A_m and B_m are Fourier coefficients, and P is the fundamental period. If we are representing the mean hourly temperature over a 24-hour period, P is 24 hours. N is the total number of harmonics.

Note that Equation 1 is an *equality*. Sampling theory shows that for T data points in period P, $T/2$ coefficients are all that are needed to exactly represent the sampled data. In practice, we can often get by with fewer coefficients. This has the added benefit of filtering out "noise" or higher frequency effects we are not interested in.

For most meteorological observations, a finite number of sines and cosines can account for all the variability. For example, if a variable is observed for each of the 12 months, the mean, five sine, and six cosine terms are sufficient to describe the annual variation completely. The sum of these terms constitute harmonic analysis. The first harmonic has a period equal to 1 year, the second harmonic has a period of 6 months, and the last resolvable harmonic, $T/2$, has a period of 2 months or six cycles a year. It is not always necessary to determine all $T/2$ harmonics.

According to Panofsky and Brier (1968), the first two or three harmonics describe the variation of a periodic function sufficiently. In fact, they argue that the first harmonic accounts for 30 percent, the second for 50 percent, and the third for 15 percent of the variance, totaling to 95 percent of the variation. MODCURVES retains the first four harmonics.

A major advantage of a Fourier series is that the modeling coefficients are all *independent* of each other. This makes computation of the coefficients easier. Also, the value of each coefficient is not a function of the total number of terms in the series (all these properties do not hold for regression). The coefficients are obtained using:

$$\bar{F} = \left(\frac{1}{T}\right)\sum_{l=1}^{T} F_l \qquad (2a)$$

$$A_m = \frac{2}{T}\sum_{l=1}^{T}\left[F_l \sin\left(\frac{2\pi}{P}mt_l\right)\right] \qquad (2b)$$

$$B_m = \frac{2}{T}\sum_{l=1}^{T}\left[F_l \cos\left(\frac{2\pi}{P}mt_l\right)\right] \qquad (2c)$$

where the ith value of F, F_i, occurs at time t_i.

2.2 Example. Suppose we wish to model the time series of mean temperature in Figure 2-2, reported in 3-hourly increments. The constant component, ($\bar{F}$), is just the mean value, or 40.375. Since $T = 8$, a value of $N = 4$ (4 harmonics) is all we need to exactly fit this data.

Hour	Temperature
0	35
3	31
6	29
9	39
12	44
15	48
18	52
21	45

Figure 2-2. Sample time-series of temperature data.

The components of the Fourier series are listed in Figure 2-3, while Figure 2-4 is a plot of the temperature cycle using values of N of 1, 2, 3, and 4. The A_N term will (in this example, A_4 will always be zero.

M	A_M	B_M
1	-9.816	-4.195
2	-1.250	-0.500
3	1.684	-0.305
4	0.000	-0.375

Figure 2-3. Fourier coefficients for the series in Figure 2-2.

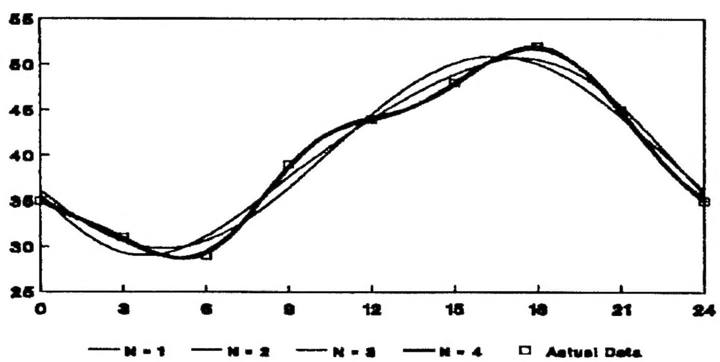

Figure 2-4. Example of a Fourier series.

Chapter 3

MODCURVES ASSUMPTIONS, LIMITATIONS, AND ACCURACY

3.1 Basic Assumptions. As with any statistical model, assumptions must be made. The assumptions place limits on a model's ability to reproduce what has been observed. Since MODCURVES is a climatological forecasting tool, it is important that these limitations are known. MODCURVES takes advantage of statistical techniques to optimize speed and accuracy while minimizing data size.

3.2 Cumulative Distributions. Since not all meteorological variables are normally distributed, MODCURVES uses the 5th, 50th, and 95th percentiles to represent the minimum, median, and maximum values of the variables. The use of percentiles eliminates the extreme values from the data, thus giving a more representative climatological view. These percentile values are placed in a time series to examine their diurnal or annual behavior.

3.3 Modeling Diurnal/Annual Behavior. A fundamental assumption of this model is that the total variation of the meteorological variable can be represented as the sum of several oscillations. Fourier or spectral analysis is used by MODCURVES to represent or predict the diurnal/annual behavior of meteorological variables. The first three harmonics, coupled with the mean, account for between 95 and 98 percent of the variance. Accordingly, MODCURVES truncates the series at the third harmonic. Although this prevents the exact replication of the original curve, the truncation of the higher frequency oscillations eliminates the unwanted "noise" in the data. Truncation also minimizes the amount of computer disk space required to store the Fourier coefficients needed to regenerate the diurnal and annual curves.

3.4 Accuracy Study. In order to determine the usefulness of MODCURVES, a simple accuracy study was conducted. Data sets of Fourier coefficients for Eglin AFB, Eielson AFB, McChord AFB, and Scott AFB were generated. The mean monthly values in the Surface Observation Climatic Summaries (SOCS) were compared to the 50th percentile (median) values from MODCURVES. Since the SOCSs do not contain monthly mean altimeter and pressure altitude, only temperature, dew-point temperature, and relative humidity could be examined. The mean absolute errors for all twelve months combined (MODCURVES value minus SOCS value) are shown in Figure 3-1.

Location	RUSSWO	MODCURVES	Temp	DewPoint	RH
Eglin	1939-86	1973-90	0.51°F	2.24°F	5.95%
Eielson	1944-87	1973-90	1.21°F	1.84°F	4.91%
McChord	1940-81	1973-90	0.44°F	0.88°F	3.88%
Scott	1938-85	1973-90	0.86°F	1.35°F	1.56%

Figure 3-1. Mean absolute difference between MODCURVES and the SOCS.

Chapter 4

MODCURVES INPUT AND OUTPUT

4.1 Restrictions. The mathematical characteristics of the Fourier series place some restrictions on the data being used. First, the time-series data must contain an even number of observations and those observations must be evenly spaced within the fundamental period of the time series. Second, the maximum number of coefficients that can be estimated is limited to *T/2*. It is impossible to use more than *T/2* harmonics to estimate a time series that has only *T* observations.

Sampling theory states that for any sampling interval *Ä*, the Nyquist critical frequency is ($f_c = 1/(2Ä)$). This critical sampling frequency for a sine wave is two sample points per cycle. If a sine wave of the Nyquist critical frequency is sampled at its positive peak value, the next sample will be at its negative trough value, and so forth—see Figure 4-1.

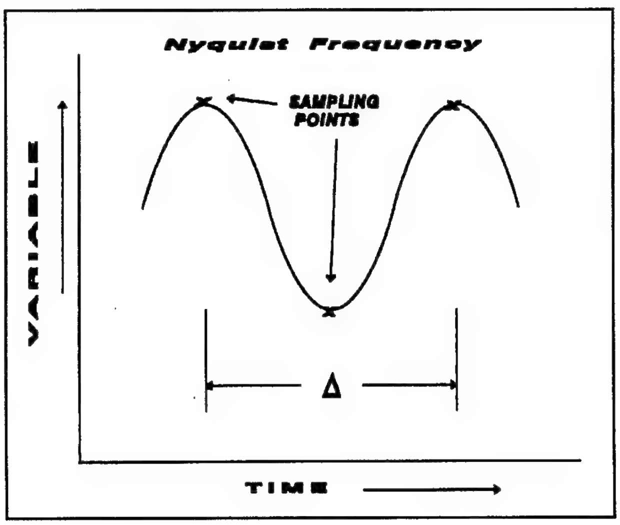

Figure 4-1. Nyquist critical frequency.

It is important to know the band-width limit of the signal or wave form you wish to model (i.e., diurnal cycle) when choosing a sampling frequency. If samples (or observations) are taken too infrequently, a phenomenon called "aliasing" takes place. When aliasing occurs, the higher frequency oscillations become masked by the lower frequency oscillations. For example, using observations less than twice a day to model a diurnal curve causes the seasonal cycles (low frequency) to hide the diurnal cycle (higher frequency). A good way to prevent this from happening is to use at least two observation points per cycle of the highest frequency present. For example, use at least two observations per day to model the diurnal cycle.

4.2 Data Input Requirements. The MODCURVES microcomputer program uses Fourier coefficients derived from time-series data. Time series are generated by a Statistical Analysis Systems (SAS) Institute Inc. program called "PROC UNIVARIATE," which produces percentile values. These percentiles are stratified by month, wind direction, and sky cover. Separate time series are created for each percentile for all five meteorological variables. Percentile values are obtained from the cumulative frequency distribution. The distribution gives the percent of the time the percentile falls below a certain value. For example, the 5th percentile means that only 5 percent of the observations in the distribution fell below that value. Similarly, the 95th percentile means that 95 percent of the observations fell below that value or that only 5 percent fell *above* that value.

MODCURVES uses a weighted adjustment of the nearest percentile value to determine which percentile a user-imposed initial condition falls on. The Fourier coefficients used by the microcomputer program are generated by a mainframe program which solves the Fourier series equation. Figure 4-2 is an example of a cumulative frequency distribution of temperature.

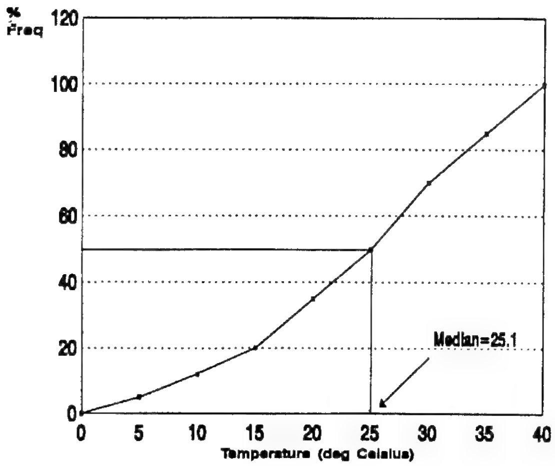

Figure 4-2. Sample cumulative frequency distribution.

Figure 4-2's horizontal axis shows the successive temperature values and the vertical axis shows the percentage frequency *less than* each temperature. The points are connected to form a smooth curve that always starts at zero percent frequency and ends at 100 percent. We are primarily interested in creating time series for the 5th percentile (lower extreme), 50th percentile (most likely value), and 95th percentile (upper extreme).

Figure 4-3 shows percentile values for Scott AFB stratified by wind direction, sky cover, month, and hour. Wind direction categories are: 1—*northerly*; 2—*easterly*; 3—*southerly*; 4—*westerly*; and 5—*all directions*. Sky cover categories are 1—*clear-scattered*; 2—*broken-overcast*; and 3—*all conditions*. Months (Mo) range from 1 to 12, hours (Hr) from 0 to 23. "Data" is the data count. The 5th, 50th, and 95th percentiles for temperature and dew point temperature in degrees Celsius follow.

4.3 Model Coefficients. The percentile values, *F*, in Figure 4-3 are functions of time; that is, *F(t)*. The Fourier series equation attempts to reproduce that function. Eight variables are required for input to the catalogued program, DNYCURVE:

- The number of evenly spaced observations in the diurnal time series data (24 observations for 24-hour reporting stations of eight observations for synoptic data).

- The number of observations in the annual time series data (a minimum of 12 observations since we are summing three harmonics; that is, four first observations per cycle.

- The hour of the first observation expressed in GMT (Z).

- Number of harmonics used to estimate the time series (MODCURVES is set to accept three harmonics).

- The number of meteorological variables for which the time series data is input (MODCURVES software is currently set to accept coefficients for five variables: *temperature, dew point, relative humidity, altimeter setting,* and *pressure altitude*).

					Temperature			Dew point		
Wind	Sky	Mo	Hr	Data	50th T°C	5th T°C	95th T°C	50th T_d°C	5th T_d°C	95th T_d°C
1	1	1	01	129	24.10	5.20	44.10	13.10	-10.90	33.10
1	1	1	02	146	24.20	4.10	43.10	14.10	-9.80	32.00
1	1	1	03	151	21.00	1.10	37.10	13.10	-12.90	29.10
4	2	12	20	110	36.00	18.20	56.00	25.10	2.10	48.00
4	2	12	21	100	35.25	19.25	60.00	27.10	4.55	47.20
4	2	12	22	95	35.10	23.00	59.00	27.00	4.10	42.50
4	2	12	23	90	35.10	25.00	55.10	27.55	11.00	42.10

Figure 4-3. Cumulative frequencies for temperature and dew-point temperature.

• The number of percentiles analyzed for each meteorological variable (MODCURVES is set to accept three percentiles: 5th, 50th, and 95th).

• The number of wind categories used to stratify the input time series data (four wind quadrants).

• The number of sky cover categories used to stratify the input time series data (Two categories: *clear/scattered* and *broken/overcast*).

4.4 Input Options. A user-friendly menu allows users to specify conditional or unconditional diurnal and annual climatologies. *Conditional* climatologies are those for which the user specifies either a wind direction category or a sky condition category. Thus, *unconditional climatologies* are those based on *all* wind and *all* sky categories. Users can specify seven options:

- station
- meteorological variable
- wind direction category
- sky-cover category
- percentile value
- monthly or annual curve
- an initial value

4.4.1 Station. The first step in accessing the diurnal/annual curves is to specify a location to display. Fourier coefficients can be generated for any station that has at least a 10-year period of record. Requests for additional stations should be directed to USAFETAC/DO.

4.4.2 Meteorological Variable. The variables that can be displayed include temperature in degrees Fahrenheit, dew point in degrees Fahrenheit, relative humidity in percent, altimeter setting in inches of mercury and pressure altitude in feet. The diurnal curve for each variable can be displayed as an unconditional climatology or conditional climatology based on some combination of wind direction and/or sky cover categories. In addition, the user has the option of entering an initial value of the meteorological variable. This option adjusts the appropriate percentile curve to that initial conditional.

4.4.3 Wind Direction Category. Users can specify one of five wind direction categories: north (315°-044°), east (045°-134°), south (135°-224°), west (225°-314°), and *all* wind directions. (NOTE: If *all* is selected for wind direction, *all* is also automatically selected for sky condition. The forecaster should note that there is no wind speed threshold to assume direction. The speed is not factored in this program. If wind is calm, use "all" wind directions).

4.4.4. Sky Cover Category. Users can specify one of three sky cover categories: clear/scattered, broken/overcast, on *all* cloud conditions (See NOTE above).

4.4.5. Percentile. Users can specify one of three percentile values: 5th percentile or low extreme, 50th percentile: the median or most likely event, or the max 95th percentile or high extreme.

4.4.6 Month or Annual Curve. Users can specify a particular month or annual data be displayed.

4.4.7 Initial Value. Finally, users can specify an initial value of the meteorological variable being displayed. This option causes the program to find the closest two curves (5th, 50th or 95th) to the initial value and uses a weighting scheme to adjust that curve to that value. It then displays the percentile of the adjusted curve.

4.5. Sample Output. USAFETAC offers two versions of MODCURVES output: CGA (Color Graphics Adapter) and EGA (Enhanced Graphics Adapter). Examples of diurnal curves from the CGA

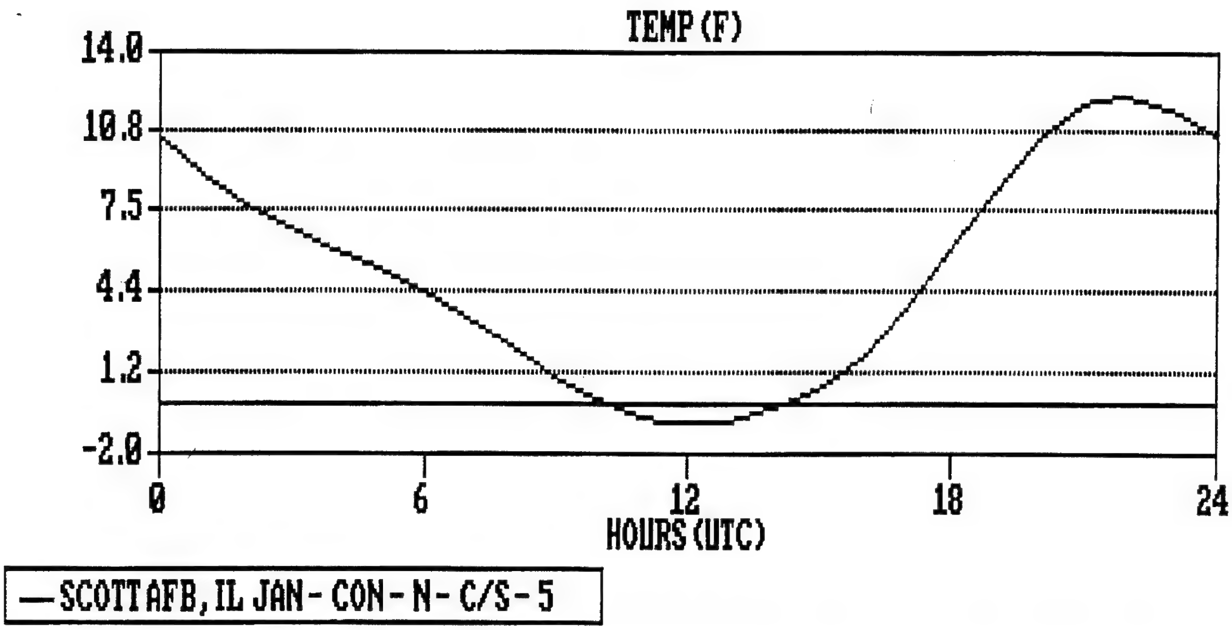

Figure 4-4. Example CGA 5th percentile plot of January temperature for Scott AFB with north winds and clear/ scattered skies.

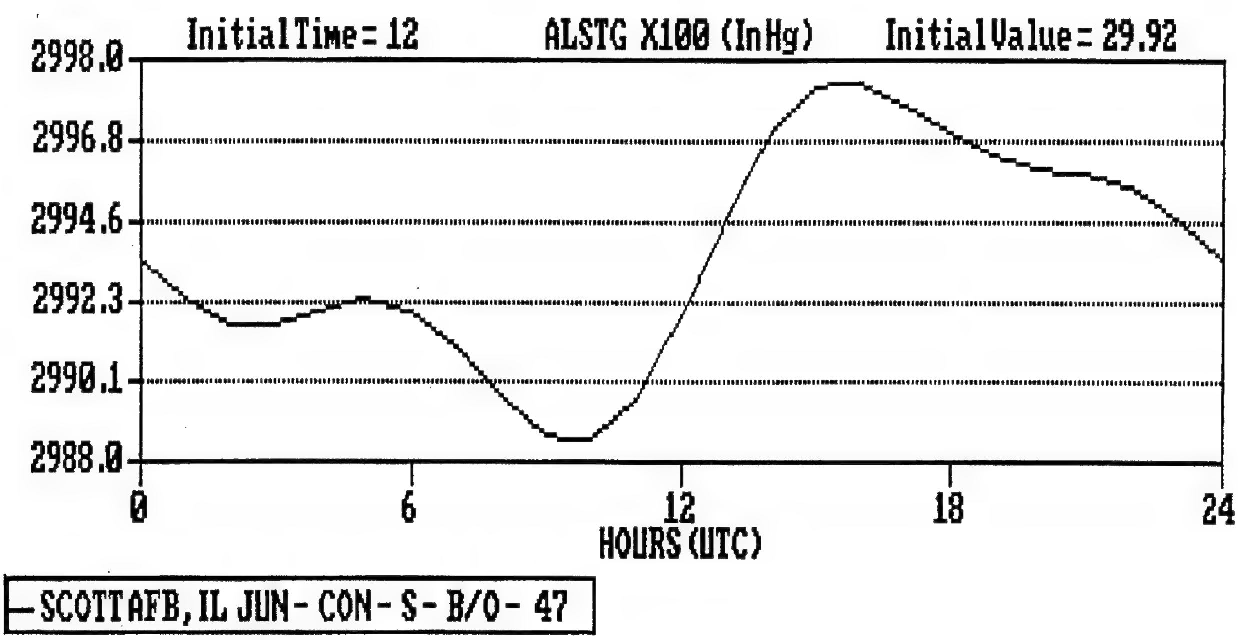

Figure 4-5. Example CGA plot of June altimeter setting for Scott AFB with south winds and broken/overcast skies. The initial condition was 29.92 at 1200Z.

Chapter 5

SUMMARY AND CONCLUSIONS

MODCURVES was developed using proven statistical techniques to make diurnal and annual changes in weather elements more readily available to the forecaster. It is designed around a user-friendly interface that allows quick access to a station's climatological database. MODCURVES allows forecasters to specify both unconditional and conditional climatologies. Tailoring the diurnal curve to current weather conditions is accomplished through an initial condition option.

MODCURVES uses time-series data for individual stations that are composited and expressed in terms of the 5th, 50th, and 95th percentiles for every hour of each month of the year. A Fourier analysis of the time series is then used to produce Fourier coefficients. These Fourier coefficients are generated using the program DNYCURVE on USAFETAC's IBM 3090 mainframe. These coefficients are downloaded from the mainframe to a floppy disk so that the MODCURVES microcomputer software can be run at base weather stations or in the field.

Climatological diurnal and annual curves for stations worldwide can be generated quickly and added to the MODCURVES database. The MODCURVES package allows forecasters to have the latest available climatology on a microcomputer.

There are two versions of MODCURVES. The CGA (Color Graphics Adapter) version runs on portable and laptop microcomputers and the EGA (Enhanced Graphics Adapter) version runs on the Zenith Z-248 and other stationary microcomputers. The use of Fourier coefficients drastically reduces the amount of data storage space needed to reproduce diurnal and annual curves based on climatological data.

ACRINABS

A_m	Fourier sine coefficient
ALSTG	Altimeter setting
AWS	Air Weather Service
B_m	Fourier cosine coefficient
DNY	Simulation Modeling Section, Aerospace Sciences, USAFETAC
DNYPCTIL	USAFETAC/DNY Fortran code that calculates percentiles of a time series
DNYCURVE	USAFETAC/DNY Fortran code that calculates Fourier coefficients
f	Frequency
F	Percentile values of a meteorological variable
F(t)	Time series function
m	Harmonic
P	Period of a function
PA	Pressure altitude
MODCLIM	Modeled climatology
MODCURVES	Modeled diurnal curves
N	Total number of observations
PROC	SAS procedure
RH	Relative humidity
SAS	Statistical analysis system
SYT	Simulation and techniques branch, USAFETAC
T	Number of data points within the period
USAFETAC	United States Air Force Technical Applications Center

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27 OSS OSW, 110 E SEXTANT AV STE 1040, CANNON AFB NM 88103-5322 1
28 OSS OSW, 1291 RYAN ST STE 105, ELLSWORTH AFB SD 57706-4801 1
49 OSS OSW, 1801 8TH ST BLDG 571, HOLLOMAN AFB NM 88330-8023 1
55 OSS/OSW, 513 SAC BLVD STE 101, OFFUTT AFB NE 68113-2094 1
57 OSS/OSW, 6278 DEPOT RD STE 102, NELLIS AFB NV 89191-7256 1
65 OSS/WX, UNIT 8025, APO AE 09720-8025 1
314 OSS/OSW, 2740 1ST ST BLDG 120, LITTLE ROCK AFB AR 72099-5060 1
319 OSS/OSW, 695 STEEN AVE STE 106, GRAND FORKS AFB ND 58205-6244 1
347 OSS/OSW, 8227 KNIGHTS WAY STE 1062, MOODY AFB GA 31699-1899 1
355 OSS/OSWF, 4360 S PHOENIX ST BLDG 4820, DAVIS MONTHAN AFB AZ 85707-4638 1
366 OSS/OSW, 665 THUNDERBOLT ST BLDG 262 RM 11, MT HOME AFB ID 83648-5401 1
416 OSS/OSW, 592 HANGAR RD BLDG 1000 STE 121, GRIFFISS AFB NY 13441-4520 1
509 OSS OSW, 745 ARNOLD AVE STE 1A, WHITEMAN AFB MO 65035-5026 1
DET 1, 549 CTS/WX, 661 7TH ST BICYCLE LAKE AAF BLDG 6212, FORT IRWIN CA 92310-5000 1
608 COS/DOOW, 245 DAVIS AVE EAST BLDG 5546 STE 245, BARKSDALE AFB LA 71110-2279 1
615 AMOG/DOMW, 575 WALDRON STREET, TRAVIS AFB CA 94535-2150 1
AETC/XOSW, 1F ST STE 2, RANDOLPH AFB TX 78150-4325 1
12 OSS DOW, H 08, 1350 5TH ST EAST, RANDOLPH AFB TX 78150-4410 1
14 OSS DOW, 595 1ST ST STE # 3, COLUMBUS AFB MS 39710-4201 1
42 OS/OSWF, 220 WEST ASH BLDG 844, MAXWELL AFB AL 36112-6608 1
45 AS/OSFWX, 817 H ST STE 102, KEESLER AFB MS 39534-2452 1

47 OSS/DOW, 541 1ST ST STE 2, LAUGHLIN AFB TX 78843-5210 1
56 OSS/OSW, 14185 WEST FALCON, LUKE AFB AZ 85309-1629 1
OL A, 56 OSS OSW, BLDG 324, GILA BEND AFAF AZ 85337-5000 1
64 OSS/DOW, 145 N DAVIS DR, REESE AFB TX 79489-5029 1
71 OSS/OSW, 301 GRITZ ST STE 52, VANCE AFB OK 73705-5412 1
80 OSS/DOW, 620 J AVENUE STE 3, SHEPPARD AFB TX 76311-2553 1
97 OSS/WXF, 603 E AVE STE 1, ALTUS AFB OK 73523-5023 1
325 OSS/OSW, STOP 22 408 FLIGHTINE RD, TYNDALL AFB FL 32403-5048 1
334 TRS TTMV, 700 H ST BLDG 4332, KEESLER AFB MS 39534-2499 1
NATIONAL AIR INTEL CTR(NAIC TATW), 4115 HEBBLE CREEK ROAD STE 33, WRIGHT-PATTERSON AFB OH 45433-5637 ... 1
NATIONAL AIR INTEL CTR(NAIC DXLA), 4115 HEBBLE CREEK ROAD STE 9, WRIGHT-PATTERSON AFB OH 45433-5613 1
AFMC/DOW, 4225 LOGISTICS AVE STE 2, WRIGHT-PATTERSON AFB OH 45433-5714 1
AFOTEC/WE, 8500 GIBSON BLVD SE, KIRTLAND AFB NM 87117-5558 1
ASC/WE, BLDG 91 3RD ST, WRIGHT-PATTERSON AFB OH 45433-6503 1
ESC/WE, 5 EGLIN ST, HANSCOM AFB MA 01731-2172 1
PL/TSML, 5 WRIGHT ST, HANSCOM AFB MA 01731-3004 1
PL/WE, 3350 ABERDEEN AVENUE, KIRTLAND AFB NM 87117-5776 1
PL/GPAA, 29 RANDOLPH RD, HANSCOM AFB MA 01731-3010 1
PL/GP, 29 RANDOLPH ROAD, HANSCOM AFB MA 01731-3010 1
ROME LAB TECH LIB, 26 ELECTRONICS PKY BLDG 106 CORRIDOR W STE 262, GRIFFISS AFB NY 13441-4514 1
46 OSS/OSWA, 601 W CHOCTAWHATCHEE AVE STE 60, EGLIN AFB FL 32542-5719 1
46 TW/TSWG, 211 W EGLIN BLVD STE 128, EGLIN AFB FL 32542-5429 1
46 TEST GROUP WE, 871 DEZONIA DRIVE BLDG 1183, HOLLOMAN AFB NM 88330-7715 1
72 OSS/OSW, 3800 A AVE BLDG 240, TINKER AFB OK 73145-9108 1
75 OSS/OSW, 5970 SOUTHGATE DR, HILL AFB UT 84056-5232 1
76 OSS OSW, 303 LUKE DR, STE 1, KELLY AFB TX 78241-5638 1
77 OSS/OSW, 3028 PEACEKEEPER STE 4, MCCLELLAN AFB CA 95652-1020 1
78 OSS/OSW, 250 EAGLE ST STE 202, ROBINS AFB GA 31098-2602 1
88 WF/OSWL, 2130 8TH ST STE 11, WRIGHT-PATTERSON AFB OH 45433-7552 1
88 WF/OSWB, 5291 SKEEL AVENUE STE 1, WRIGHT-PATTERSON AFB OH 45433-5231 1
88 WF/OSWA, 2049 MONAHAN WAY BLDG 91, WRIGHT-PATTERSON AFB OH 45433-7204 1
412 OSS/OSW, 85 S FLIGHTLINE RD BLDG 1200, EDWARDS AFB CA 93524-6460 1
WESTOVER BASE WEATHER STATION, BLDG 7091 RM 123, WESTOVER ARB MA 01022-5000 1
AFSOC DOOWO, 100 BARTLEY ST, HURLBURT FLD FL 32544-5273 1
16 OSS/OGSW, 150 BENNETT AVE BLDG 90730, HURLBURT FIELD FL 32544-5727 1
HQ AFSPACECOM/DOOW, 150 VANDENBERG ST STE 1105, PETERSON AFB CO 80914-4200 1
DET 2, SMC/TDOR (WEATHER) ONIZUKA ASN, 1080 LOCKHEED WAY BOX 044, SUNNYVALE CA 94089-1235 1
14 AF/DOW, 747 NEBRASKA AVE STE 22, VANDENBERG AFB CA 93437-6268 1
21 OSS/OSW, 125 W HAMILTON AVE, PETERSON AFB CO 80914-1220 1
30 WS, 900 CORRAL RD BLDG 21150, VANDENBERG AFB CA 93437-5002 1
30 WS/DOV, 900 CORAL RD BLDG 21150, VANDENBERG AFB CA 93437-5001 1
45 WS /DOO, 1201 MINUTEMAN ST, PATRICK AFB FL 32925-3238 1
50 OSS/OSW, 300 O'MALLEY AVE STE 146, FALCON AFB CO 80912-3026 1
50 WS/DOWO, 300 O'MALLEY STE 146, FALCON AFB CO 80912-7160 1
90 OSS/DOW, 7505 SABER RD BLDG 1250 RM 1AF, F E WARREN AFB WY 82005-2684 1
341 OSS/DOW, 7224 FLIGHTLINE DR ROOM 209, MALMSTROM AFB MT 59402-7526 1
AMC/DOWO, 402 SCOTT DR UNIT 3A1, SCOTT AFB IL 62225-5302 1
AMC/DOWR, 402 SCOTT DR UNIT 3A1, SCOTT AFB IL 62225-5302 1
TACC/WXF, 402 SCOTT DRIVE RM 132, SCOTT AFB IL 62225-5029 1
60 OSS/WXF, 611 E STREET, TRAVIS AFB CA 94535-5024 1
92 OSS/OSW, 901 WEST BOSTON STE 115, FAIRCHILD AFB WA 99011-8529 1
305 OSS/OSW, 1730 VANDENBERG AVENUE, MCGUIRE AFB NJ 08641-5509 1
375 OSS/OSW, 433 HANGAR RD, SCOTT AFB IL 62225-5029 1
377 ABW OTW, 3400 CLARK AVE SE, KIRTLAND AFB NM 87117-5776 1
380 OSS/OSW, 301 ARIZONA AVE STE 1AF, PLATTSBURGH AFB NY 12903-2705 1
436 OSS/OSW, 501 EAGLE WAY ST, DOVER AFB DE 19902-7504 1
437 OSS/OSW, 221 S BATES ST ROOM 130, CHARLESTON AFB SC 29404-5426 1
615 AMOG/DOMW, 575 WALDRON ST, TRAVIS AFB CA 94535-2150 1
722 OSS/OSW, 2645 GRAEBER ST STE 3, MARCH AFB CA 92518-2264 1
WEATHER READINESS TRAINING CENTER (WRTC), PO BOX 465 RTE 1, CAMP BLANDING, STARKE FL 32091-9703 1
104 WEATHER FLIGHT, 2701 EASTERN BLVD, BALTIMORE MD 21220-2899 1
105 WEATHER FLIGHT TNANG, 240 KNAPP BOULEVARD, NASHVILLE TN 37217-2538 1

107 WEATHER FLIGHT, 26000 SOUTH ST BLDG 1516, SELFRIDGE ANGB MI 48045-5024 1
110 WEATHER FLIGHT, HQ 131 TFW, 10800 NATURAL BRIDGE RD, BRIDGETON MO 63044-2371 1
111 WEATHER FLIGHT, 14657 SNEIDER STREET, ELLINGTON ANGB TX 77034-5586 1
113 WEATHER FLIGHT, 824 E VANATTI COURT, TERRE HAUTE IN 47803-5012 1
116 WEATHER FLIGHT, 307 6TH STREET, MCCHORD AFB WA 98439-1201 1
120 WEATHER FLIGHT, 19089 BRECKENBRIDGE AVE, AURORA CO 80011-9527 1
121 WEATHER FLIGHT, 3252 E PERIMETER ROAD, ANDREWS AFB MD 20762-5011 1
122 WEATHER FLIGHT, 400 RUSSELL AVENUE, NEW ORLEANS NAS LA 70143-5200 1
123 WEATHER FLIGHT, 6801 CORNFOOT ROAD, PORTLAND OR 97218-2797 1
125 WEATHER FLIGHT, 4200 N 93RD EAST AVENUE, TULSA OK 74115-1699 1
126 WEATHER FLIGHT, 1919 EAST GRANGE AVE, MILWAUKEE WI 53207-6298 1
127 WEATHER FLIGHT, P.O. BOX 19061 FORBES ANGB, TOPEKA KS 66619-5000 1
131 WEATHER FLIGHT, 1 TANK DESTROYER BLVD BOX 35, BARNES ANGB MA 01085-1385 1
140 WEATHER FLIGHT (PAANG), 201 FAIRCHILD STREET, WILLOW GROVE ARS PA 19090-5320 1
146 WEATHER FLIGHT, 300 TANKER ROAD #4254 PITTSBURG IAP, CORAOPOLIS PA 15108-4254 1
154 WEATHER FLIGHT, CAMP ROBINSON, NORTH LITTLE ROCK AR 72118-2200 1
156 WEATHER FLIGHT, 5225 MORRIS FIELD DRIVE, CHARLOTTE NC 28208-5797 1
159 WEATHER FLIGHT, RT 1, BOX 465 CAMP BLANDING, STARKE FL 32091-9703 1
164 WEATHER FLIGHT, RICKENBACKER IAP 7556 SOUTH PERIMETER ROAD, COLUMBUS OH 43217-5910 1
165 WEATHER FLIGHT, 1019 OLD GRADE LANE, LOUISVILLE KY 40213-2678 1
181 WEATHER FLIGHT, 8150 W JEFFERSON BLVD, DALLAS TX 75211-9570 1
195 WEATHER FLIGHT, 106 MULCAHEY DRIVE BLDG 106, PORT HUENEME CA 93041-4003 1
200 WEATHER FLIGHT, 291 THUNDERBOLT STREET ROOM 8, SANDSTON VA 23150-2513 1
202 WEATHER FLIGHT, BLDG 3138, OTIS ANGB MA 02542-5001 1
203 WEATHER FLIGHT, 125 PINEGROVE ST FT INDIANTOWN GAP, ANNVILLE PA 17003-5154 1
204 WEATHER FLIGHT, 3306 FEIEBELKORN ROAD, MCGUIRE AFB NJ 08641-6004 1
207 WEATHER FLIGHT, 3912 W MINNESOTA ST, INDIANAPOLIS IN 46241-4064 1
208 WEATHER FLIGHT, 206 AIRPORT DR, ST PAUL MN 55107-4098 1
209 WEATHER FLIGHT, 2210 W 35 STREET, BLDG 9 RM 119, AUSTIN TX 78703-1222 1
210 WEATHER FLIGHT, 1280 SOUTH TOWER DRIVE, ONTARIO ANGB CA 91761-7627 1
AFGWC/DO, 106 PEACEKEEPER DR STE 2N3 MBB 39, OFFUTT AFB NE 68113-4039 1
AWS/XO, 102 LOSEY ST BLDG 105, SCOTT AFB IL 62225-5206 4
AWS/XOTT, 102 WEST LOSEY ST, SCOTT AFB IL 62225-5205 1
AWS/XOXT, 102 LOSEY ST BLDG 1521, SCOTT AFB IL 62225-5206 1
AWS/XOT, 102 W LOSEY ST BLDG 1521 RM 105, SCOTT AFB IL 62225-5206 1
AWS/XOO, 102 WEST LOSEY ST, SCOTT AFB IL 62225-5000 1
AWS/XOS, 102 WEST LOSEY ST BLDG 1521 RM 105, SCOTT AFB IL 62225-5206 1
AWSTL, FL4415 859 BUCHANAN ST, SCOTT AFB IL 62225-5118 50
COMBAT WEATHER FACILITY, 595 INDEPENDENCE RD BLDG 91027, HURLBURT FLD FL 32544-5618 1
OL A, USAFETAC, 151 PATTON AVENUE RM 120, ASHEVILLE NC 28801-5002 1
DTIC-FDAC, CAMERON STATION, ALEXANDRIA VA 22304-6145 1
HQ USEUCOM ECJ33-OD-WE, UNIT 30400 BOX 1000, APO AE 09128-4209 1
NATO LMS/OPS, STAFF METEOROLOGICAL OFFICER, APO AE 09724 1
USCENTCOM CCJ3-OW, 7115 S BOUNDARY BLVD BLDG 540, MACDILL AFB FL 33621-5101 1
USSOCCENT SOCJ2- SWO, 7115 S BOUNDARY DRIVE, MACDILL AFB FL 33621-5101 1
USSOCOM SOJ3 OW, 7701 TAMPA POINT BLVD, MACDILL AFB FL 33621-5323 1
USSOUTHCOM SWO, UNIT 0640, APO AA 34001-5000 1
USSTRATCOM J 315, 901 SAC BLVD STE 1B29, OFFUTT AFB NE 68113-6700 1
62 OSS/OSW, 1172 E STREET RM 127, MCCHORD AFB WA 98438-1008 1
89 OSS/OSW, 1240 MENOHER DR BLDG 1220, ANDREWS AFB MD 20762-6511 1
NCDC LIBRARY, 151 PATTON AVENUE LIBRARY, ASHEVILLE NC 28801-2733 1
NOAA CENTRAL LIBRARY, 1315 EAST-WEST HIGHWAY STE 2000, SILVER SPRING MD 20910 1
NOAA CENTRAL LIBRARY, 1315 EAST WEST HIGHWAY, SILVER SPRING MD 20910 1
NOAA/MASC LIBRARY MC5, 325 BROADWAY, BOULDER CO 80303-3328 1
PACAF/DOWO, 25 E ST STE I232, HICKAM AFB HI 96853-5426 1
PACAF/DOW, 25 E ST STE I232, HICKAM AFB HI 96853-5426 1
3 OSS/WE, 7TH ST BLDG 32235, ELMENDORF AFB AK 99506-3097 1
3 ASOS/WEATHER, 3112 BROADWAY STE 7, EIELSON AFB AK 99702-1850 1
DET 1, 3 ASOS/GEW, BLDG 1558, FT WAINWRIGHT AK 99703-5200 1
8 OSS/OSW, UNIT 2139 BLDG 2858, APO AP 96264-2139 1
15 OSS/OSW, 800 HANGAR AVE, HICKAM AFB HI 96853-5244 1
18 OSS/OSTL, UNIT 5177 BOX 10, APO AP 96363-5177 1

18 OSS/OSW, UNIT 5177 BOX 40, APO AP 96368-5177 1
25 ASOS/DOW, 1102 WRIGHT AVE, WHEELER AAF HI 96854-5200 1
OL A, 25 ASOS, BRADSHAW AFB HI, APO AP 96556-5000 1
35 OSS/OSW, UNIT 5011, APO AP 96319-5011 1
36 OSS/OSW, UNIT 14035 BOX AF, APO AP 96543-4035 1
DET 1, 36 OSS/OSJ, PSC 489 BOX 20, FPO AP 96536-0051 1
51 OSS/OSW, UNIT 2163, APO AP 96278-2163 1
199 WEATHER FLIGHT, 1102 WRIGHT AVENUE, WHEELER AAF HI 96854-5200 1
354 OSS/OSW, 1215 FLIGHT LINE AVE STE 2, EIELSON AFB AK 99702-1520 1
374 OSS/OSW, UNIT 5222, APO AP 96328-5222 1
OL A, 374 OSS, UNIT 45007, APO AP 96343-0085 1
607 WEATHER SQUADON/DOOF, UNIT 15173, APO AP 96205-0108 1
607 WEATHER SQUADRON/DOO, UNIT 15173 BLDG 1506, APO AP 96205-0108 1
607 COS/DOW, UNIT 2072, APO AP 96278-2072 1
DET 1, 607 WEATHER SQUADRON, UNIT 15674, APO AP 96258-0674 1
DET 2, 607 WEATHER SQUADRON, UNIT 15200 BLDG S 819, APO AP 96271-0136 1
OL A DET 1, 607 WEATHER SQUADRON, UNIT 15675, APO AP 96257-0675 1
OL A, 607 WEATHER SQUADRON, UNIT 15630 BLDG 1610, APO AP 96208-0195 1
OL A DET 2, 607 WEATHER SQUADRON, UNIT 15673, APO AP 96218-0673 1
OL B DET 1, 607 WEATHER SQUADRON, UNIT 15118, APO AP 06224-0420 1
OL B, 607 WEATHER SQUADRON, BLDG S 252 UNIT 15242, APO AP 96205-0015 1
OL C, 607 WEATHER SQUADRON, BLDG S 3101 RM 4, APO AP 96297-0626 1
611 OSS/OSW, 6900 9TH ST STE 205, ELMENDORF AFB AK 99506-2250 1
C/O FT RICHARDSON NCOIC, 611 OSS/WE, 6900 9TH STREET STE 205, ELMENDORF AFB AK 99506-2250 1
USSPACECOM J3W, 250 S PETERSON BLVD STE 116, PETERSON AFB CO 80914-3220 1
OL A, AFCOS, FT RICHIE MD 21719-5010 1
DET 3, AFFTC/DOSW, PO BOX 19070, LAS VEGAS NV 89132-0070 1
MAURY OCEANOGRAPHIC LIBRARY, NAVOCEANO N4312, BLDG 1003, STENNIS SPACE CTR MS 39522-5001 1
OCEANOGRAPHER OF THE NAVY, US NAVAL OBSERVATORY BLDG 1 3450 MASS AVE, WASHINGTON DC 20392-5421 1